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Optimization of Structural Damage Repair with Single and Double-Sided Composite Patches through the Finite Element Analysis and Taguchi Method

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Abstract

Over the last four decades, numerous studies have been conducted on the use of bonded composite repairs for aircraft structures. These studies have explored the repair of damaged plates through experimental, numerical, and analytical methods and have found that bonded composite repairs are effective in controlling crack damage propagation in thin plates. The use of double-sided composite repairs has been found to improve repair performance within certain limits. This study focuses on these limits and optimizes double-sided composite repairs by varying adhesive bond and composite patch parameters. The optimization process begins with a finite element analysis to determine the stress intensity factor (SIF) for various variables and levels, followed by the application of the Taguchi method to find the optimal combination of parameters for maximizing the normalized SIF. In conclusion, we successfully determined the stress intensity factor (SIF) for various variations and normalized it for optimization. An optimization study was then performed using the Taguchi design and the results were analyzed. Our findings demonstrate the repair performance of bonded composite patches using a cost-effective and energy-efficient approach. © 2023 by the authors.

Author Keywords

composite patch; cracked plate; finite element method; stress intensity factor; Taguchi method

Index Keywords

Adhesives, Aircraft manufacture, Airframes, Cost effectiveness, Cracks, Energy efficiency, Numerical methods, Plates (structural components), Repair, Stress intensity factors, Structural optimization, Taguchi methods; Bonded composite repairs, Composite patches, Composite repair, Cracked plate, Double sided, Optimisations, Performance, Stress-intensity factors, Structural damages, Taguchi's methods; Finite element method

References

- Achour, T., Bouiadjra, B., Serier, B.
  Numerical analysis of the performances of the bonded composite patch for reducing stress concentration and repairing cracks at notch
  (2003) *Comput. Mater. Sci*, 28, pp. 41-48.
- Albedah, A., Bouiadjra, B.B., Mhamdia, R., Benyahia, F., Es-Saheb, M.
  Comparison between double and single sided bonded composite repair with circular shape
  (2011) *Mater. Des*, 32, pp. 996-1000.
- Ergun, E., Tasgetiren, S., Topcu, M.
  Stress intensity factor estimation of repaired aluminum plate with bonded composite patch by combined genetic algorithms and FEM under temperature effects
  (2012) *Indian J. Eng. Mater. Sci*, 19, pp. 17-23.
- Kwon, Y.W., Lee, W.Y., McGee, A.S., Hart, D.C., Loup, D.C., Rasmussen, E.A.
  Analytical model for prediction of reduced strain energy release rate of single-side-patched plates
  (2013) *Appl. Compos. Mater*, 20, pp. 1321-1339.

- Aabid, A., Hrairi, M., Ali, J.S.M., Abuzaid, A.
Stress concentration analysis of a composite patch on a hole in an isotropic plate
(2018) *Int. J. Mech. Prod. Eng. Res. Dev*, 6, pp. 249-255.

- Aabid, A., Hrairi, M., Ali, J.S.M., Abuzaid, A.
Numerical analysis of cracks emanating from hole in plate repaired by composite patch
(2018) *Int. J. Mech. Prod. Eng. Res. Dev*, 4, pp. 238-243.

- Taghizadeh, H., Chakherlou, T.N.
Fatigue behavior of interference fitted Al-alloy 7075-T651 specimens subjected to bolt tightening
(2019) *Proc. Inst. Mech. Eng. Part L J. Mater. Des. Appl*, 233, pp. 1879-1893.

- Seriari, F.Z., Benachour, M., Benguediab, M.
Fatigue crack growth of composite patch repaired Al-alloy plates under variable amplitude loading
(2018) *Frat. Integrità Strutt*, 12, pp. 43-56.

- Yala, A.A., Megueni, A.
Optimisation of composite patches repairs with the design of experiments method
(2009) *Mater. Des*, 30, pp. 200-205.

- Fekih, S.M., Albedah, A., Benyahia, F., Belhouari, M., Bouiadjra, B.B., Miloudi, A.
Optimisation of the sizes of bonded composite repair in aircraft structures
(2012) *Mater. Des*, 41, pp. 171-176.

- Liu, X., He, Y., Qiu, D., Yu, Z.
Numerical optimizing and experimental evaluation of stepwise rapid high-pressure microwave curing carbon fiber/epoxy composite repair patch
(2019) *Compos. Struct*, 230, p. 111529.

- Aabid, A., Hrairi, M., Abuzaid, A., Ali, J.S.M.
Estimation of stress intensity factor reduction for a center-cracked plate integrated with piezoelectric actuator and composite patch
(2020) *Thin-Walled Struct*, 158, p. 107030.

- Aabid, A., Hrairi, M., Ali, J.S.M., Sebaey, T.A.
A review on reductions in the stress-intensity factor of cracked plates using bonded composite patches
(2022) *Materials*, 15.

- Kalagi, G., Buradi, A., Kaladgi, A.R., Madhusudhana, H., Prasanna, H.U., Yadav, R.Y., Afzal, A., Saleel, C.A.
Erosion wear behavior of glass fiber hybridized flax and sisal fabric hybrid composites with taguchi experimental design
(2021) *Mater. Today: Proc*, 47, pp. 5901-5906.

- Zarrinzadeh, H., Kabir, M., Deylami, A.
Experimental and numerical fatigue crack growth of an aluminium pipe repaired by composite patch
(2017) *Eng. Struct*, 133, pp. 24-32.

- Otani, T., Sumihira, W., Kobayashi, Y., Tanaka, M.
Density-based topology optimization of thin plate structure with geometric nonlinearity using a three-dimensional corotational triangle element formulation
(2022) *Struct. Multidiscip. Optim*, 65, p. 282.

- Şimşek, S., Kahya, V., Adıyaman, G., Toğan, V.
Damage detection in anisotropic-laminated composite beams based on incomplete

modal data and teaching–learning-based optimization
(2022) *Struct. Multidiscip. Optim*, 65, p. 332.

- Zhang, C., Li, Y., Jiang, B., Wang, R., Liu, Y., Jia, L.
Mechanical properties prediction of composite laminate with FEA and machine learning coupled method
(2022) *Compos. Struct*, 299, p. 116086.

- Berrahou, M., Benzineb, H., Serier, M.
Analysis of the adhesive damage for different shapes and types patch's in Aircraft Structures corroded with an inclined crack
(2022) *Frat. Integrità Strutt*, 60, pp. 331-345.

- Bouzitouna, W.N., Oudad, W., Belhamiani, M., Belhadri, D.E., Zouambi, L.
Elastoplastic analysis of cracked aluminum plates with a hybrid repair technique using the bonded composite patch and drilling hole in opening mode I
(2020) *Frat. Integrità Strutt*, 14, pp. 256-268.

- Baghdadi, M., Serier, B., Salem, M., Zaoui, B., Kaddouri, K.
Modeling of a cracked and repaired Al 2024T3 aircraft plate: Effect of the composite patch shape on the repair performance
(2019) *Frat. Integrità Strutt*, 13, pp. 68-85.

- El-Sagheer, I., Taimour, M., Mobtasem, M., Abd-Elhady, A., Sallam, H.E.-D.M.
Finite element analysis of the behavior of bonded composite patches repair in aircraft structures
(2020) *Frat. Integrità Strutt*, 14, pp. 128-138.

- Rao, P.S., Hardiman, M., O'Dowd, N.P., Sebaey, T.A.
Comparison of progressive damage between thermoset and thermoplastic CFRP composites under in-situ tensile loading
(2021) *J. Compos. Mater*, 55, pp. 1473-1484.

- Alshahrani, H., Sebaey, T.A.
Effect of Embedded Thin-Plies on the Charpy Impact Properties of CFRP Composites
(2022) *Polymers*, 14.

- Ahmad, F., Mehboob, H., Abbassi, F., Hong, J.W., Zghal, J., Mehboob, A.
Numerical investigation to evaluate the energy effect on the impact resistance of an aircraft carbon fiber-reinforced polymer composite
(2022) *Mech. Adv. Mater. Struct*, 29, pp. 4457-4467.

- Alshahrani, H., Sebaey, T.A., Allah, M.M.A., El-baky, M.A.A.
Quasi-static axial crushing performance of thin-walled tubes with circular hole discontinuities
(2022) *J. Compos. Mater*, 56, pp. 4195-4218.

- Ouinas, D., Bouiadjra, B.B., Serier, B.
The effects of disbonds on the stress intensity factor of aluminium panels repaired using composite materials
(2007) *Compos. Struct*, 78, pp. 278-284.

- Benyahia, F., Albedah, A., Bouiadjra, B.B.
Analysis of the adhesive damage for different patch shapes in bonded composite repair of aircraft structures
(2014) *Mater. Des*, 54, pp. 18-24.

- Papadopoulos, G.A., Badalouka, B., Souyiannis, J.
Experimental study of the reduction at crack-tip stress intensity factor KI by bonded

patches
(2008) *Int. J. Fract*, 149, pp. 199-205.

- Aabid, A., Hrairi, M., Ali, J.S.M., Abuzaid, A.
Effect of bonded composite patch on the stress intensity factors for a center-cracked plate
(2019) *IIUM Eng. J*, 20, pp. 211-221.

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